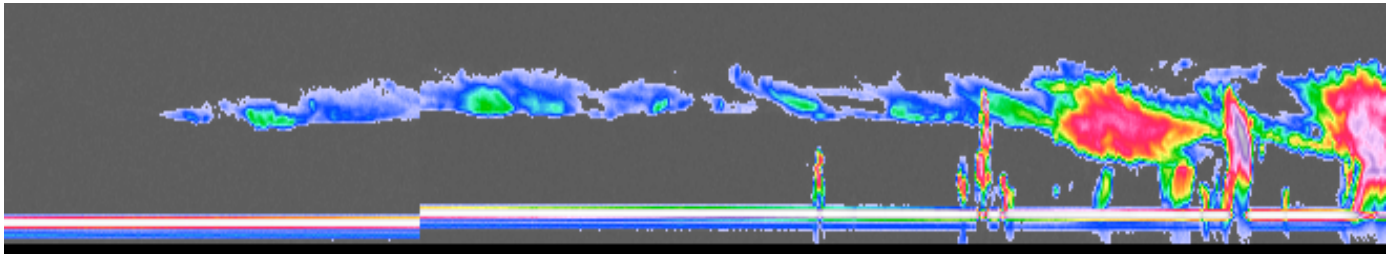
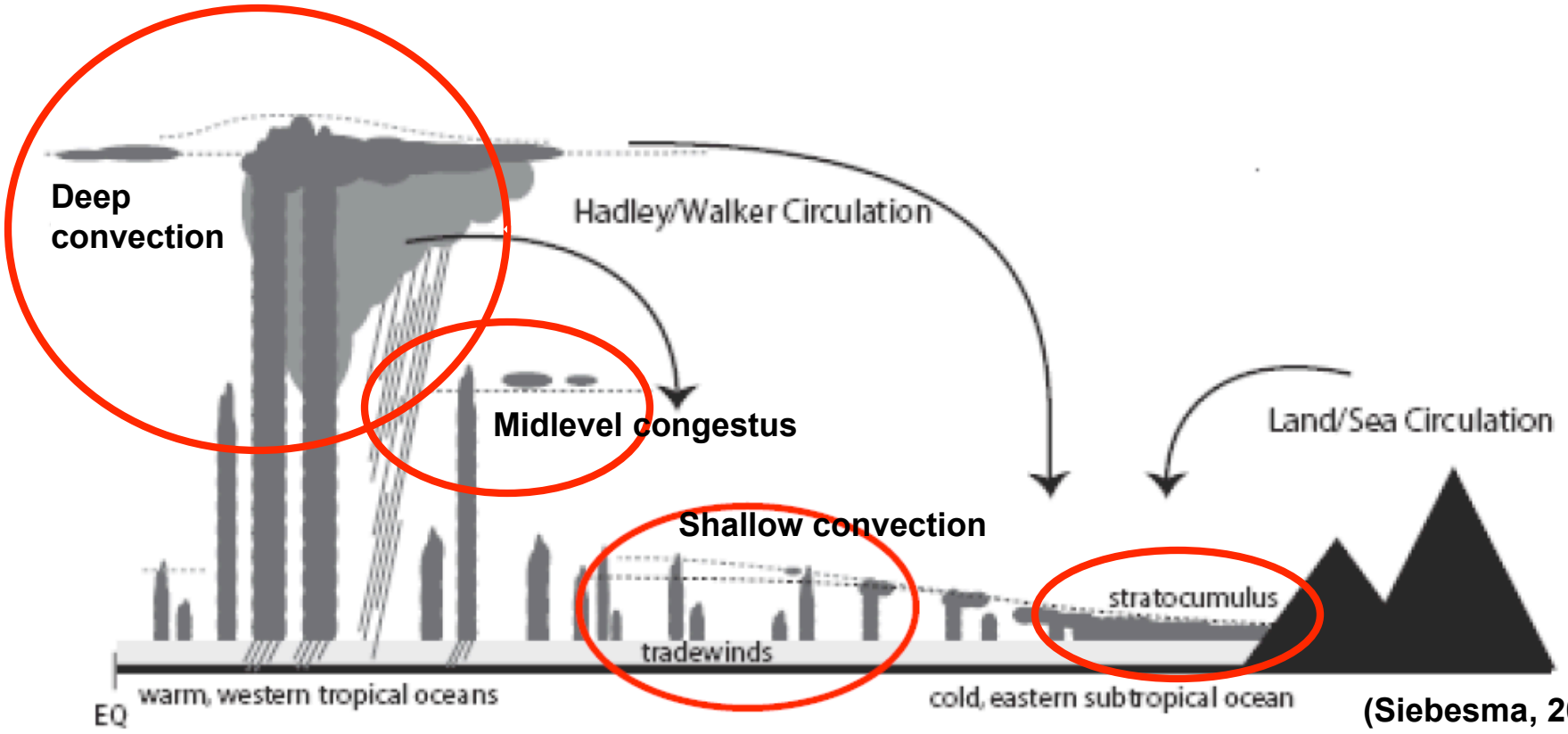
CLOUD MODELING CHALLENGES FOR CLIMATE CHANGE SIMULATION



Tony Del Genio
NASA/GISS

ACE SWG Meeting, 6/19/08

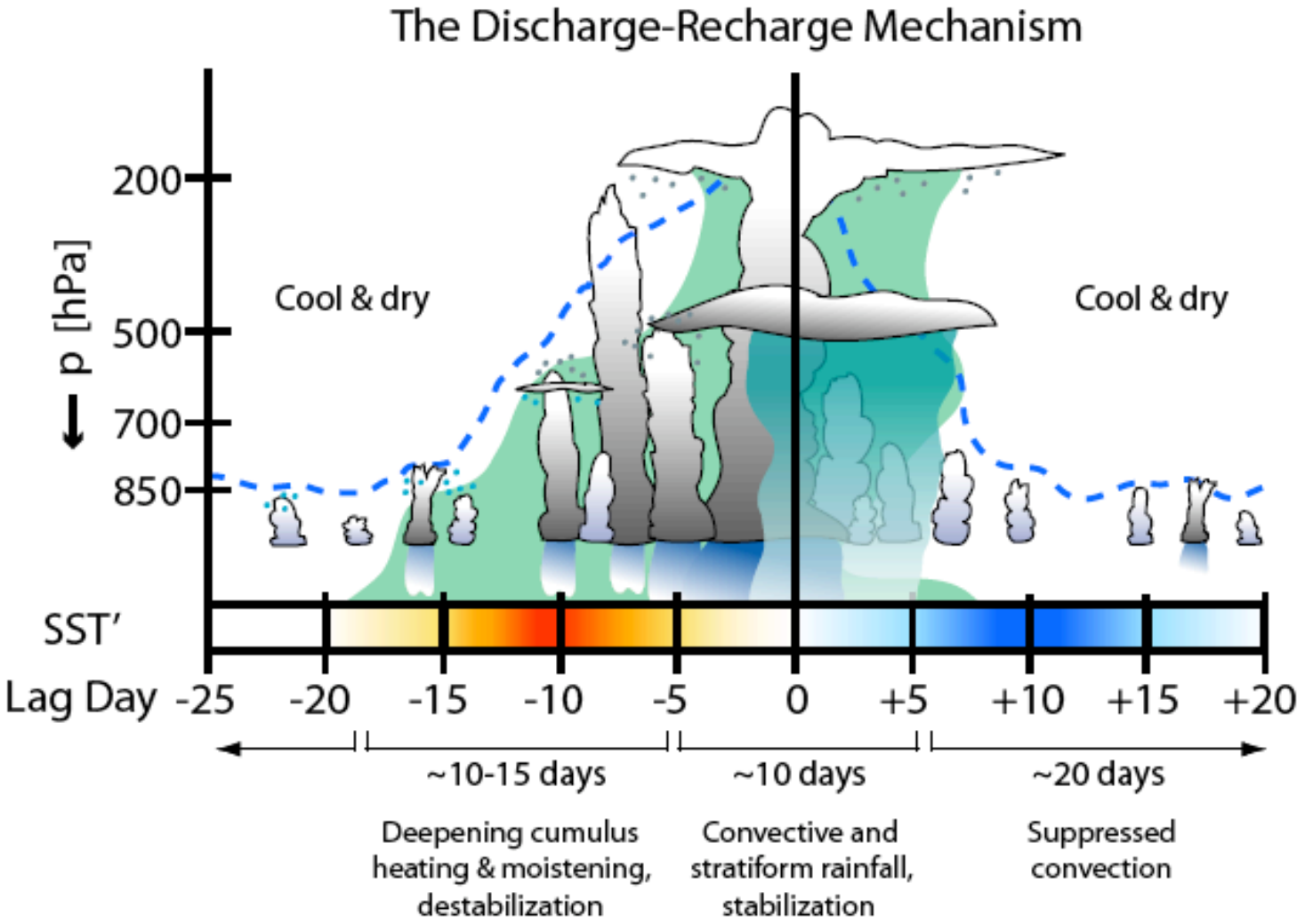
Some key cloud types for climate change simulations



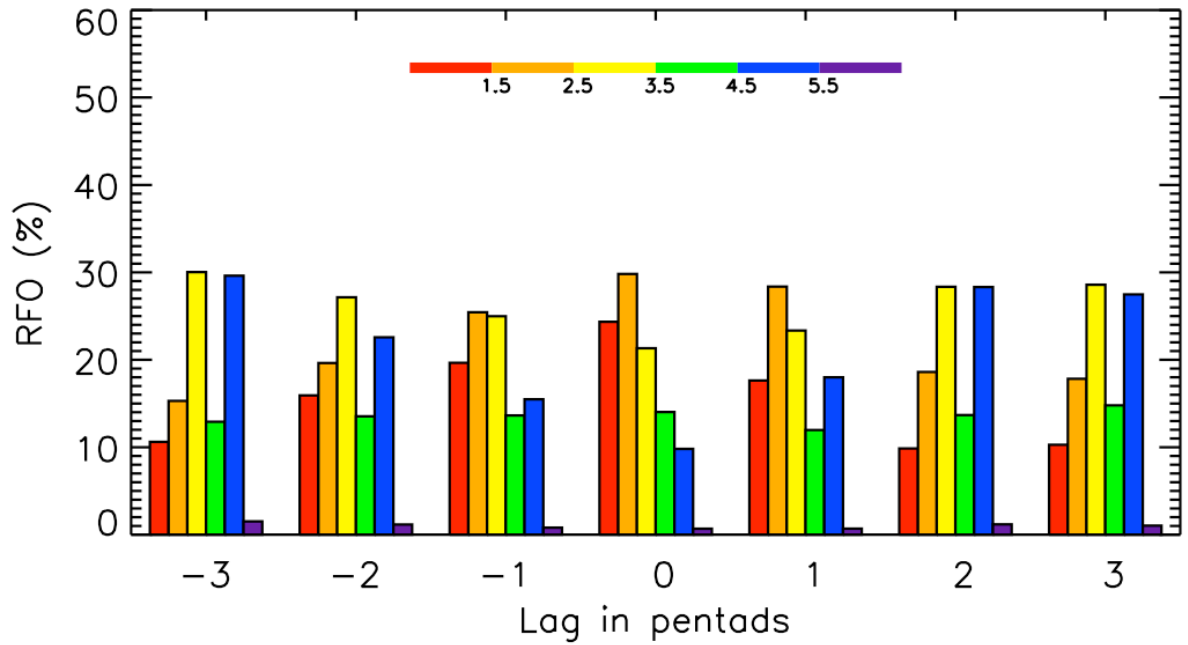
(Siebesma, 2008)

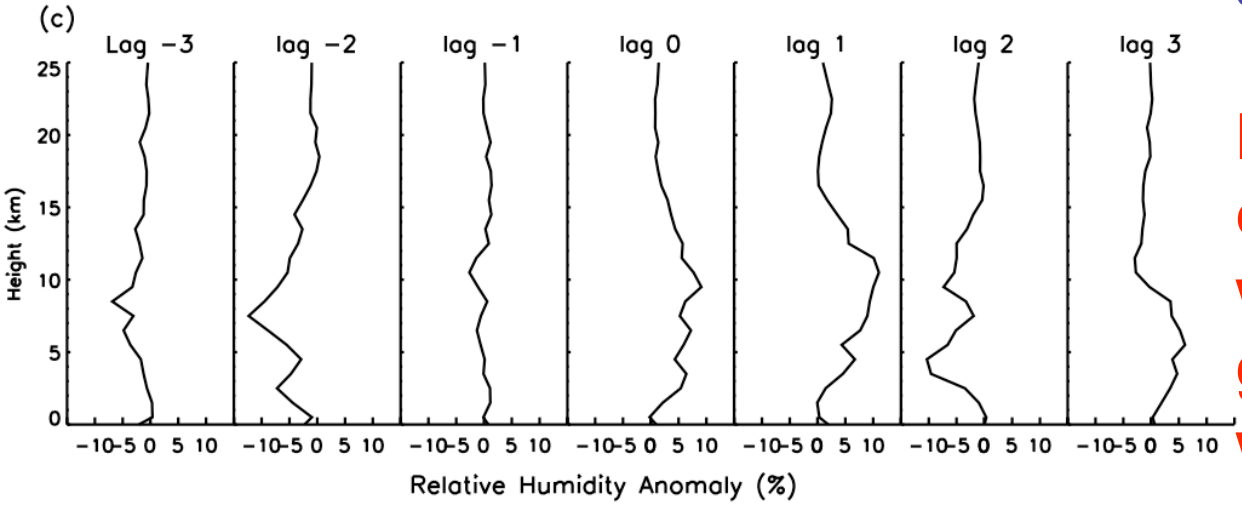
What controls the transition from one type to another?

MJO onset and decay: Transition from shallow _ midlevel _ deep convection may be controlled by free troposphere humidity



(Benedict and Randall, 2007)





red = deep convective
orange = anvil
yellow = congestus
green = thin cirrus
blue = shallow Cu
violet = marine Sc

Transition visible in ISCCP cloud cluster categories and in RH profiles

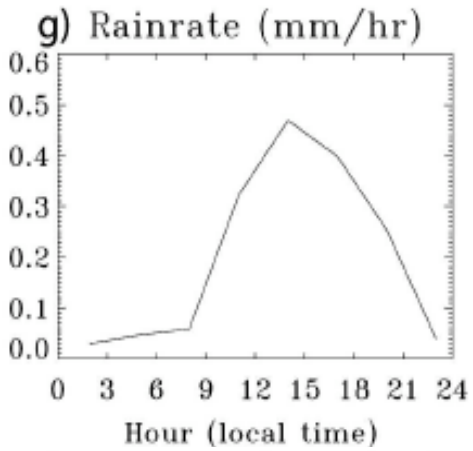
But ISCCP gets cloud top wrong – what radar/lidar are good at – scanning will help sampling

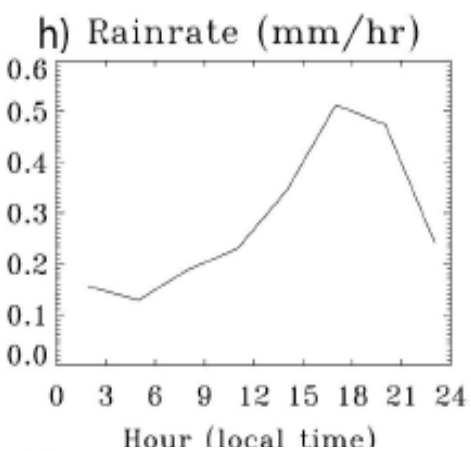
(Chen and Del Genio, 2008)

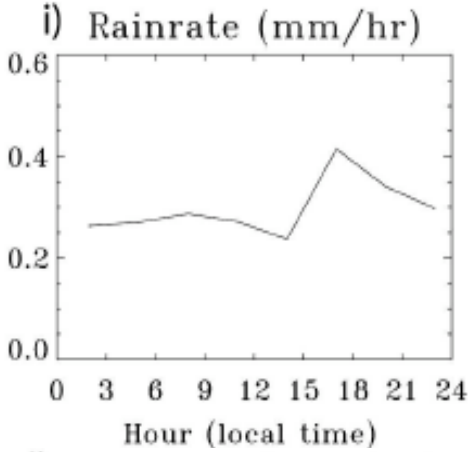
Transition from shallow to deep convection also a big issue for diurnal cycle and thus SW cloud forcing

CAM3 MMF OBS

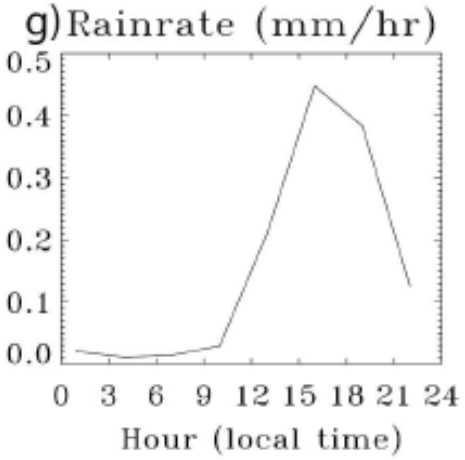
TRMM LBA

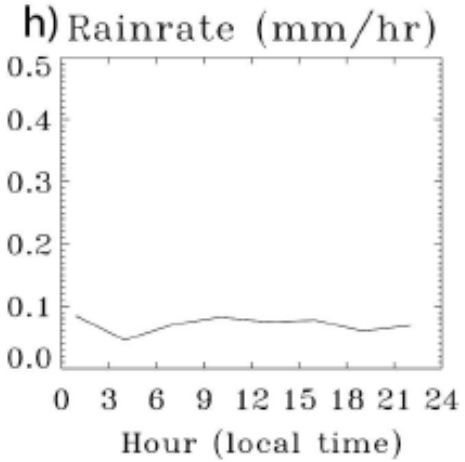


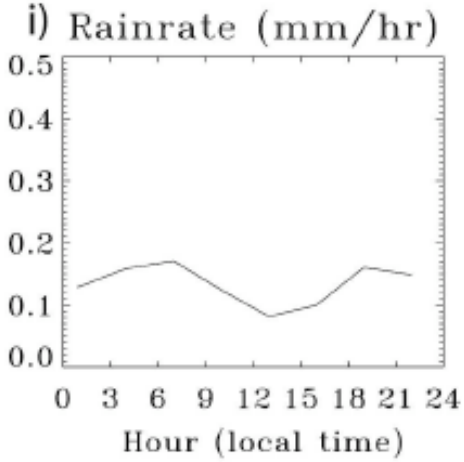




ARM SGP



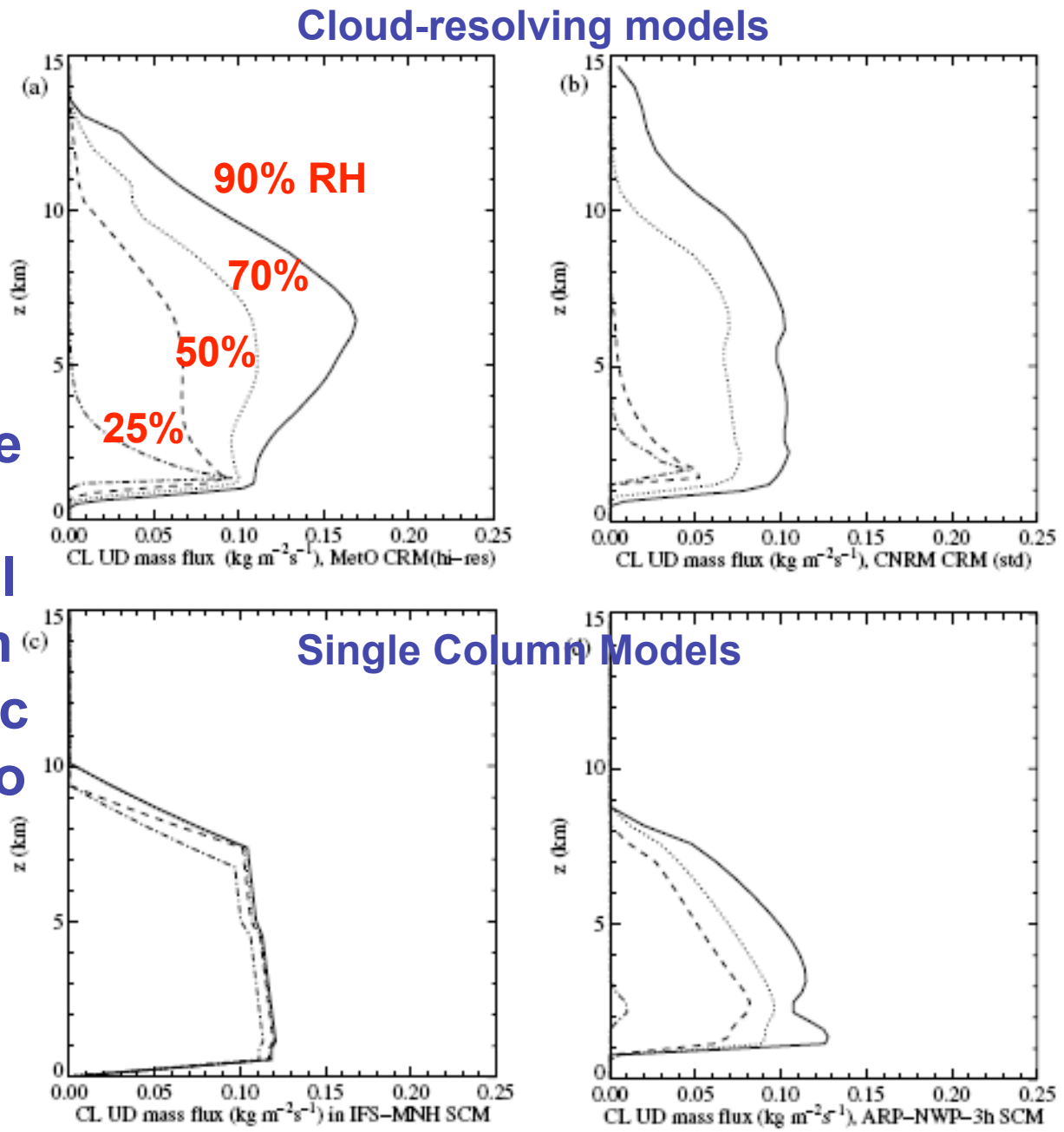




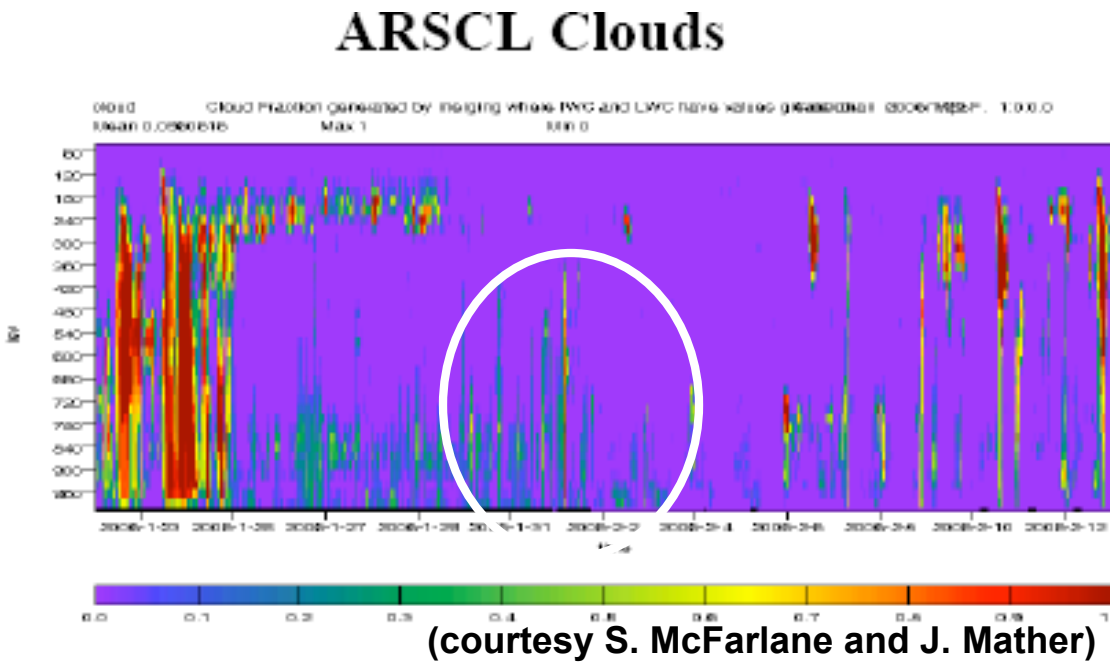
(DeMott et al., 2008)

GCM cumulus parameterizations are not sensitive enough to free troposphere humidity to capture the transition from shallow to midlevel to deep convection – need atmospheric state information to evaluate cloud models

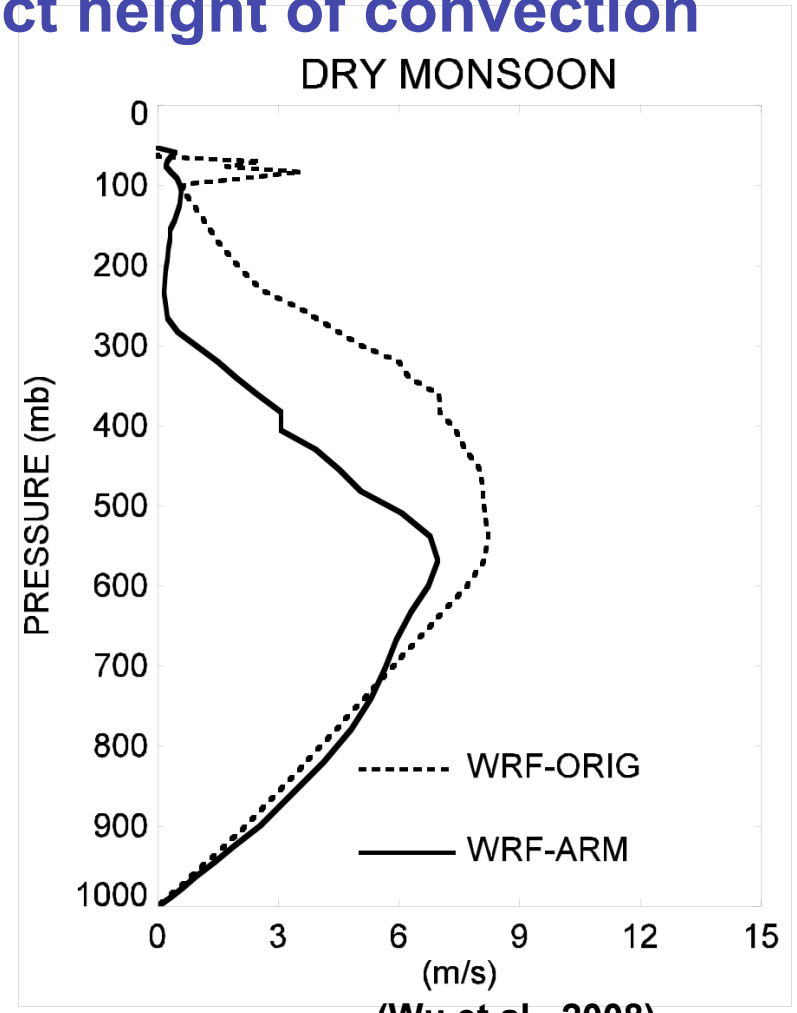
(Derbyshire et al., 2004)



But reanalysis provides state information, right?
…ERA-40 reanalysis advective forcing is not accurate enough for WRF to simulate correct height of convection



(courtesy S. McFarlane and J. Mather)

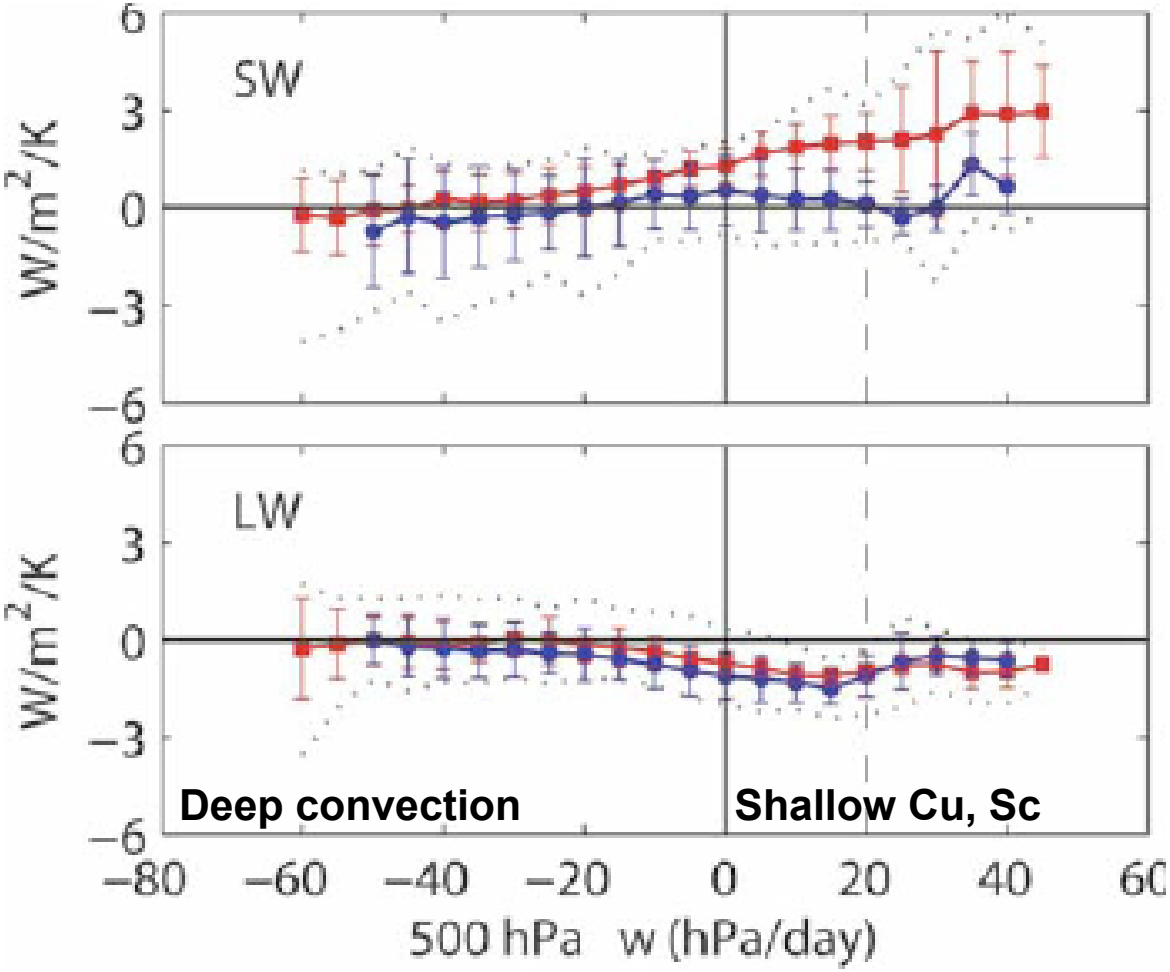


(Wu et al., 2008)

WRF-ORIG: Forced by ERA-40 (CAPE = 948 J/kg)

WRF-ARM: Adjusted to obs at boundary (CAPE = 1662 J/kg)

Much of the existing difference in climate sensitivity among IPCC AR4 GCMs is in how low clouds change with warming



Red = models with positive cloud feedback

Blue = models with negative cloud feedback

(Bony and Dufresne, 2005)

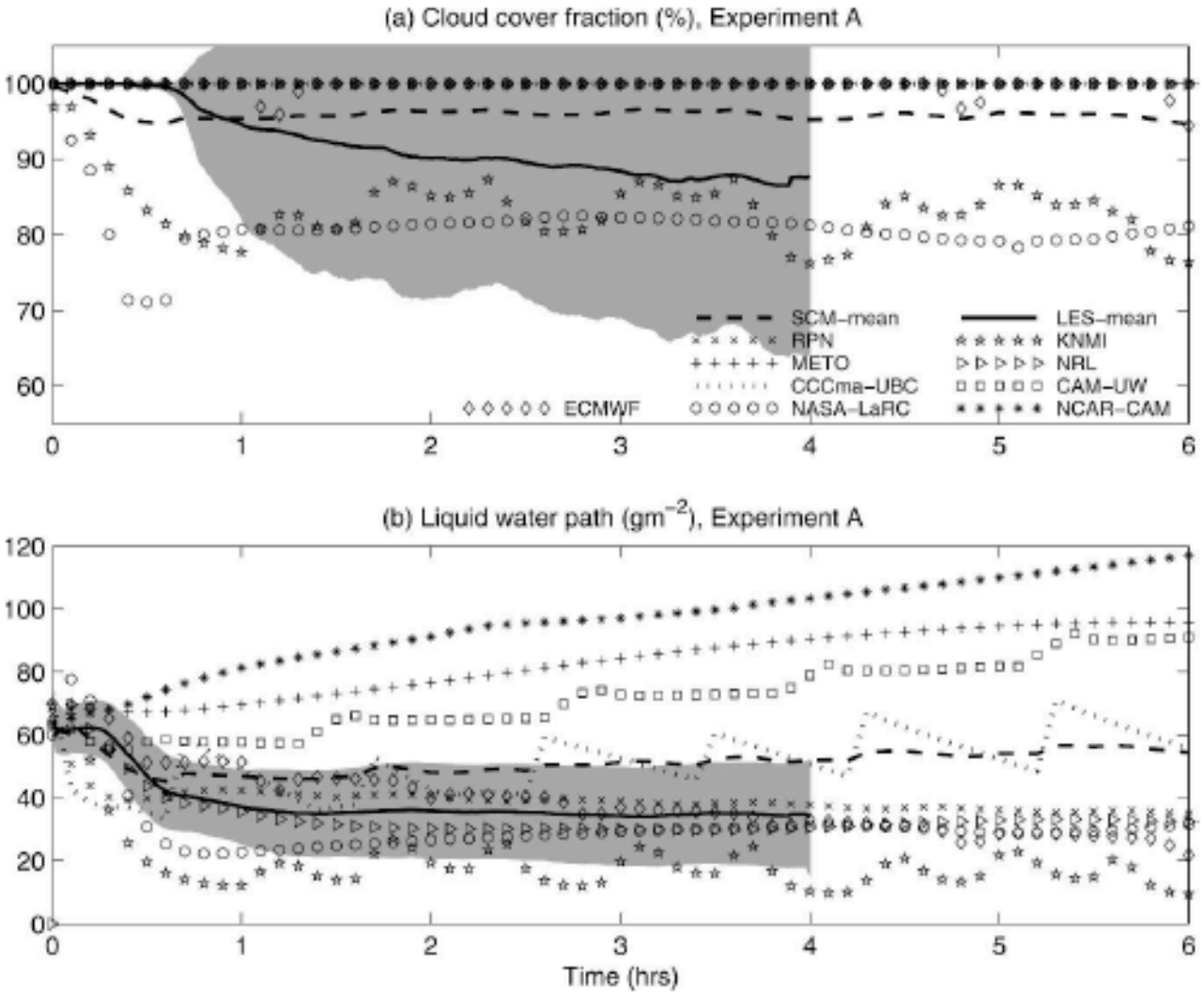


FIG. 2. Time series of total cloud cover fraction and vertical integrated liquid water path from experiment A. Gray shading indicates the $\pm 1\ \sigma$ (standard deviation) range of the LES results.

SCMs have a terrible time simulating marine Sc

Even LES models have problems

Why is it so difficult?

(Zhu et al., 2005)

Scattered cumulus
~10% cloud cover

Cumulus
rising into
stratocumulus
~50% cloud cover

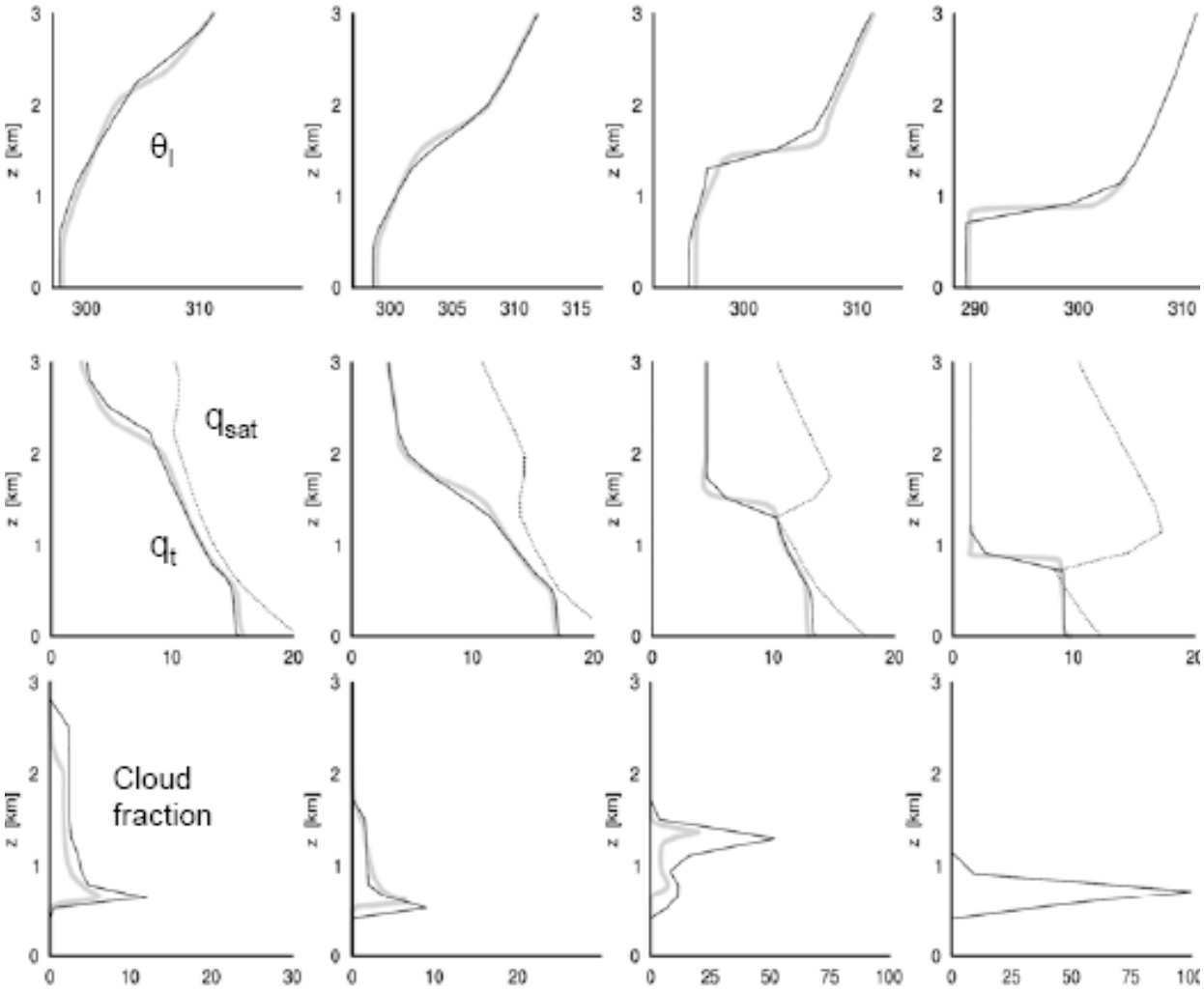
Stratocumulus
Overcast

RICO
Precipitating

BOMEX
Non-precipitating

ATEX

DYCOMS2



T, q changes over 10s – 100s of meters make the difference between almost clear and overcast skies over the tropical and subtropical oceans

Significant cloud below 1 km, where CloudSat cannot see

(Siebesma, 2008)

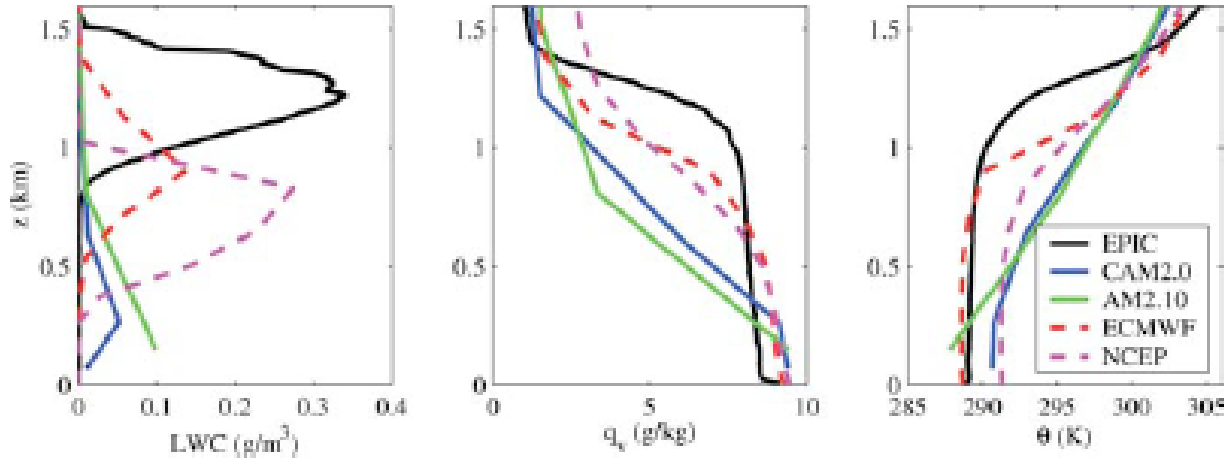


FIG. 10. Comparison of 6-day buoy-period mean cloud and thermodynamic profiles—liquid water content (LWC), water vapor (q_v), and potential temperature (θ)—from EPIC with ECMWF and NCEP–NCAR operational analyses for the same time and location, and with Oct climatological profiles for recent versions of two leading GCMs.

(Bretherton et al., 2004)

Can we resolve these vertical structure details?

- **GCMs: No**
- **Reanalyses: No**
- **Passive remote sensing: No**

Some issues that need to be addressed for ACE to be useful to cloud modelers

- Need simultaneous information on T, q, _ profiles and at high resolution – wind, water vapor, temperature lidars? – really, need another A-train concept

- Need to capture clouds near the surface that may control cloud feedback

- In any case, a moot point if U.S. doesn't begin to support cloud model development at levels comparable to European modeling groups